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Original article

Characteristics of the Red Leached Fersialitic soils of the high southern plain of Pinar del Río

Características de los suelos Fersialíticos Rojos Lixiviados de la llanura meridional alta de Pinar del Río

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ABSTRACT: Soil fertility is considered a determining factor in the availability of nutrients for plants, mainly in tropical regions where transformation and translocation processes of substances are more energetic in soil formation compared to temperate regions. This problem is related to the climatic factor, mainly rainfall and temperature, which are more accentuated in these areas. Considering the above, a detailed edaphological study of "El Pitirre" Productive Base Unit, in Pinar del Río province, was carried out through the application of the Dokuchaevian comparative geographic method, with the main objective of evaluating the edaphological properties. For this, different factors of soil formation are diagnosed, which with their morphological, physical and chemical properties, the soil formation process is established; which is the main basis for soil classification in Cuba. On these results, a new genetic type of soils was diagnosed, the Red Leached Fersialitic, with several subtypes according to relief differences and anthropic causes. In addition, it was shown that the soils are of the ABtC profile type, deep, red, clayey, formed from ancient Quaternary sediments rich in basalt, in undulating to hilly relief, with acid reaction pH and have a low to very low content of assimilable potassium and phosphorus.

Key words: edaphology, classification, fertility.

RESUMEN: La fertilidad de los suelos se considera un factor determinante en la disponibilidad de nutrientes para las plantas, principalmente en las regiones tropicales donde los procesos de transformación y translocación de sustancias son más enérgicos en la formación de los suelos en comparación con las regiones templadas. Esta problemática está relacionada por el factor climático, principalmente las precipitaciones y la temperatura que son más acentuadas en estas zonas. Teniendo en cuenta lo anterior, se realizó un estudio edafológico detallado de la Unidad Base Productiva "El Pitirre", en la provincia Pinar del Río, mediante la aplicación del método geográfico comparativo dokuchaeviano, con el objetivo principal de evaluar las propiedades edafológicas. Para ello, se diagnostican los diferentes factores de formación de suelos, lo que con sus propiedades morfológicas, físicas y químicas, se establece el proceso de formación de suelo; que es la base principal de la clasificación de los suelos de Cuba. Sobre estos resultados, se diagnosticó un nuevo tipo genético de suelos, el Fersialítico Rojo Lixiviado, con varios subtipos según las diferencias del relieve y por causas antrópicas. Además, se demostró que los suelos son del tipo de perfil ABtC, profundos, de color rojo, arcillosos, formado de sedimentos cuaternarios antiguos ricos en basalto, en relieve ondulado a alomado, con pH de reacción ácida y poseen un contenido de bajo a muy bajo en potasio y fósforo asimilables.

Palabras clave: edafología, clasificación, fertilidad.

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INTRODUCTION

Approximately two years ago, the Science, Technology and Innovation Entity (ECTI) "Sierra Maestra" was established and it is progressing in the development of various experimental projects in which plants and seeds with high protein values are used. At present, together with other national organizations, various medicinal and food products are being developed, such as the use of mulberry (*Morus alba* L.), stevia (*S. rebaudiana* Bertoni), the Jamaican flower (*Hibiscus sabdariffa* L.), acerola (*Malpighia emarginata*) and turmeric (*C. longa* L.). They have properties that control sugar in diabetics and incorporate vitamins (1-5) and sacha inchi cultivation (*Plukenetia volubilis* L.), from whose seeds an oil-containing omega 3, 6 and 9 is extracted (6-8).

The Fersialitic Soil Grouping is characterized by its ABC profile, medium to shallow, formed by the process of fersialitization, with a fersialitic diagnostic horizon. They are established on different parent rocks (carbonate, igneous, basic, ultrabasic, intermediate, and acidic). In the last version of Cuban soil classification within this group of soils there are three genetic types: Reddish Brown Fersialitic, Red Fersialitic and Yellowish Fersialitic (9).

However, in the research carried out in "El Pitirre" Farm (93.36 ha) a Fersialitic Red Leached soil (FrsRL) was found, which does not exist as a genetic type in the current 2015 version of Cuban soil classification, but which was in the 1999 version, occupying an extension of 73.77 ha. Considering the above, the objective of this work is to evaluate the genetic-geographic characteristics of these soils formation.

MATERIALS AND METHDS

Location and selection of the study area

The agricultural unit "El Pitirre" is one of the farms that make up the ECTI "Sierra Maestra", which is geographically located 10 km north of Los Palacios municipality in Pinar del Río province; between the coordinates of Latitude: 317, 319 N and Longitude: 269, 271 E.

In the investigation of the soils, the dokuchaevian comparative geographic method was applied, which consists of the study of the soil profile morphology, its characteristics, distribution and its relation with the soil formation factors (SFF), establishing at the same time the processes of soil formation and its classification (10). This method provides recommendations to improve soil fertility and productivity. The study was carried out in an area of approximately 100 ha, using a 1:10 000 map of the region as a cartographic base. Six soil profiles were taken according to differences in relief, five of which were analyzed.

Characterization and classification of the soils under study

The soils were classified according to the Cuban Soil Classification (9), in addition to the international classifications: Soil Taxonomy (11) and World Reference Base (12).

Physical analysis

The analyses were carried out at the Soil Physics Laboratory of the Department of Biofertilizers and Plant Nutrition from National Institute of Agricultural Sciences (INCA). The evaluations and analytical methods used were the following:

- Mechanical composition: by the modified Bouyoucos method, using sodium pyrophosphate to eliminate organic matter and sodium hexametaphosphate as a dispersant.
- Texture: determined using the textural triangle.
- Bulk density (BD): in the field using 100 cm^3 cylinders.
- Determination of natural or field moisture: using the gravimetric method.
- Organic Carbon Reserves (OCR) by the international method:
- OCR ($Mg\ ha^{-1}$) = Organic Carbon (%) x BD ($kg\ dm^{-3}$) x thickness (cm).

where:

Organic Carbon (%) = Organic Matter (%)/1,724.

Chemical analysis

The samples were analyzed in the laboratory mentioned above, using the methods described below:

- pH in water: it was determined according to the potentiometric method, soil: water ratio 1:2.5.
- pH in potassium chloride: soil: solution ratio 1:2.5.
- OM: by Walkley & Black method.
- Exchangeable cations: by extraction method with ammonium acetate 1 mol L-1 at pH 7 and determination by complexometry (Ca^{++} and Mg^{++}) and flame photometry (K^+ and Na^+).
- Assimilable phosphorus: by Oniani's method.
- Assimilable potassium is calculated from the results obtained for exchangeable potassium.

RESULTS AND DISCUSSION

Soil formation factors

"El Pitirre" farm is currently located in two main forms of relief; a strongly undulating relief, with slopes ranging between 6 and 12 % and some areas with undulating relief with gentler slopes of 2-4 %. It is located in the highest part of the southern coastal plain of Pinar del Río (100-120 m a.s.l.), in a foothill adjacent to Sierra de los Órganos. The present relief evolved in the Quaternary Period from a flat to gently undulating relief, to strongly undulating due to neotectonic movements that took place during the formation of the southern coastal plain (13).

The source material is from ancient Quaternary sediments, represented by basic and ultrabasic rock materials over large limestone boulders; both formations are from the early Quaternary period. It is proposed that in the ancient Quaternary, Cuba´s climate was very humid (14,15). For this reason, it is estimated that, in this ancient terrace level of the South Plain of Pinar del Río, under a very rainy ancient climate, there were sediments with large limestone rocks (larger than 10-15 cm) and on top of it, sediments with fragments of basic and ultrabasic rocks, which are found in the Sierra.

The current climate is tropical sub-humid with rainfall ranging from 1500 to 1600 mm annually, with the highest incidence in the summer (May to October) and average temperature around 24-25 ºC (Paso Real de San Diego Agrometeorological Station, Pinar del Río, 2019).

The primary vegetation may have been semi-deciduous forest, currently largely replaced by marabu secondary vegetation (*Dichrostachys cinérea* L.).

Soil formation processes

Due to the interaction of the FFS, from the Quaternary period, relatively weathered soils were formed, and on the other hand, due to the tropical climate and over time, these have been subject to the intense washing process that could have been more evolved than at present, possibly remaining as roots of Ferrallitic soils formed in the past. The above mentioned is corroborated by the distribution of the genetic map of Cuba soils 1:250 000, in which they appear classified as Red Latosolic little evolved formed of materials transported from basic and ultrabasic rocks (16).

From the FFS data interaction, together with the characteristics of profile morphology, as well as analytical results, it can be diagnosed that in these soils there are currently manifested processes of formation of fersialitization and leaching. In addition, there is the presence of an argillic horizon by results of the texture analysis. On the basis that they are soils with accumulation of free iron by the red color, and have sialitic composition by the data of exchangeable cations in 100 g of clay, it gives rise to the process of phersialitization (17).

The *fersialitization* process is diagnosed by the Sum of Changeable cations (SCC), that although the soils are under a process of marked weathering, it is not proper of ferralitization, since the SCC is higher than 20 cmol in the soil, which means that in clay it must be higher and for ferralitization it must be lower than 20 cmol in 100 g of clay, according to the Cuban Soil Classification (9). Following what it is established in this classification, for the establishment of the diagnostic profile the B-horizon is placed with the sub-indicator frs, which indicates that the soil is Fersialitic. The *leaching* process is presented by the enrichment in clay in the Bt horizon (textural B), which in all cases there is a difference of 8% or more in relation to the A horizon (typical of argillic horizons, for soils that have 40 % or more in the A horizon), as a result of this process. In the establishment of the diagnostic profile, it is placed with the sub-indicator t, which means textural.

Types of soils and their characteristics

Fersialitic Red Leaching Soil, fluffy and humic (FrsRLmh)

This soil occupies the high and stable part of the relief with preserved vegetation, either pasture or grassland between established groves. It is represented by profiles 1 and 4, with a diagnostic profile Amh-Btfrs-BCgr-CRca, occupying an area of 5 ha, with a reddish-brown color well marked in the Bt horizon and moderately deep with an underlying horizon rich in stones of hard and rounded limestone rocks at 45-50 cm depth. The morphological, chemical and physical characteristics of both soil profiles are presented below:

According to the results of the mechanical analysis and the texture determination (Table 1) they have loam-clay-sandy to clay-sandy texture in the A horizon and more clayey in Bt. The structure is very good in the A horizon, of the granular type, among other characteristics, it is classified as fluffy due to its color, structure and base saturation (18,19).

The surface soil reaction is slightly acidic, low in assimilable phosphorus and very low in assimilable potassium. The surface $Ca^{+2}Mg^{+2}$ ratio in profile 1 is

Table 1. FrsRLmhsoil mechanical composition

Horizon	Depth (cm)	Ag (2.0-0.2)	Af (0.2-0.02)	Lg (0.02-0.01)	Lf (0.01-0.002)	Clay < 0.002	Texture
Profile 1							
$A_{11}h$	0-14	46.53	6.00	8.00	4.00	35.47	Sandy clay loam
$A_{12}h$	14-29	33.25	8.00	6.00	5.28	47.47	Clayey
Bt	29-41	33.25	10.00	4.00	7.28	47.63	Clayey
Profile 4							
$A_{11}m$	0-10	38.53	8.00	6.00	4.00	43.47	Sandy clay
$A_{12}m$	10-24	37.25	2.00	12.00	2.00	46.75	Clayey
Bt	24-55	33.81	4.00	4.00	5.28	52.91	Clayey
CRca	55-70	39.25	8.00	6.00	2.00	44.75	Sandy clay

Ag: coarse sand, Af: fine sand, Lg: coarse silt, Lf: fine silt between 7 and 8, which is high; however, in profile 4 it is ideal, being in the range between 4 and 5 (Table 2).

They have an OM content of 4 % or more in a thickness of 20 cm in the superficial part, so they are classified as humic as well as fluffy (9). For this reason, the COR are relatively high in both profiles, mainly between 64 and 84 Mg ha^{-1} for the 0-20 cm layer, in correspondence with the soil humification degree under preserved conditions (Table 3).

Fersialitic Red Leached erogenic soil (FrsRLer)

This soil is present in the slope phase or in a high and stable part, under recent planting with very little vegetation cover or is prepared for planting, without vegetation cover. In the process of clearing marabú for planting, soil losses about 20 cm occurred, which are still evident in very recent plantations (one year or less) due to the low vegetation cover between the bushes.

Due to erosion losses, they are classified as erogenous soil subtypes. They are represented by profiles 2, 5 and 6. Profiles 2 and 5 are little eroded, while profile 6 is strongly eroded, since it lost a large part of the A horizon and part of the B horizon, with a BA horizon emerging on the surface.

These erogenous subtype soils occupy an area of 68.77 ha, those that are gently eroded are of profile or Aer-Bt-B3gr-CRca type and those moderately eroded are of profile or BA-Bt-Bgr-CRca type. They are deeper than the previous ones, reaching up to 80-85 cm depth if the B3gr horizon is included. In the results of the mechanical analysis and the determination of the texture (Table 4), they have a clayey to clayey sandy horizon on the surface, which passes to a Bt horizon, with well differentiated coatings.

Soils with 2:1 clay minerals, such as the Fersialitic soils, generally in wavy-hilly reliefs, are easily eroded when used for agricultural production (20). This particularity is more accentuated when the B horizon presents vertic properties or the argillic horizon. In the specific case of the farm's red ferric soils, they are leached by the presence of the argillic horizon. Due to the above, these soils are easily eroded and in this case they are eroded by anthropogenic influence; that is why they are classified as erogenic, following what is established in the 2015 Cuban Soil Classification.

When analyzing the physical-chemical characteristics of the FrsRLer soil (Table 5), the results reflected that the pH on surface is of slightly acid reaction, which decreases in depth, reaching values lower than 5.0 in potassium chloride, but without reaching less than 4.5, so it is deduced that they are not Alitic. As in the previous profiles, they have low and very low assimilable phosphorus and potassium contents. In relation to exchangeable bases, as in the other soils, calcium and magnesium predominate, with an adequate Ca^{+2}/Mg^{+2} ratio (between 2 and 6).

The FrsRL soil, which has a neutral to moderately acid reaction, is different from the Red Phersialitic soils formed from limestone in Cuba, characterized (20,21). This FrsRL soil is similar to the one initially classified in Cuba as Red Soil (22) and to the one called Red Soil in India, China (23) and as Krasnozion in the warm zone of the former USSR (10,24,25).

Table 2. Physical-chemical characteristics of the soil FrsRLmh

Depth	pH		OM	P_2O_5	K_2O	Exchangeable cations (cmol kg^{-1})				
(cm)	H_2O	KCl	(%)	mg 100g^{-1}	mg 100g^{-1}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Sum
Profile 1										
0-14	6.6	6.5	4.90	3.9	9.4	27.5	3.5	0.10	0.20	31.3
14-29	6.5	6.5	4.25	3.7	7.5	26.0	5.0	0.14	0.16	31.3
29-41	6.4	6.3	2.94	4.6	7.0	30.0	3.0	0.14	0.15	33.3
Profile 4										
0-10	5.8	5.8	4.40	3.7	7.0	19.0	5.0	0.13	0.15	24.3
10-24	6.0	5.9	4.47	5.0	6.6	17.0	3.5	0.12	0.14	20.8
24-55	6.7	6.4	1.91	5.0	5.1	16.5	4.5	0.10	0.11	21.2
55-70	6.8	6.6	1.67	3.9	3.3	15.5	4.0	0.08	0.07	19.7

Table 3. FrsRLmh soil carbon content and reserves

Depth	OM	C	Dv	W	Reserves of C	Reserves of C (Mg ha^{-1})		
(cm)	(%)	(%)	(kg dm^{-3})	(%)	(Mg ha^{-1})	0-20	0-30	0-50
Profile 1								
0-14	4.90	2.84	1.17	17	46.5	64	83	Nd
14-29	4.25	2.47	1.39	21	44.1			
29-41	2.94	1.71	1.21	24	24.9			
Profile 4								
0-10	4.40	2.55	1.69	16.82	43.1	84	111	148
10-24	4.47	2.59	1.58	19.25	57.3			
24-55	1.91	1.11	1.66	16.71	57.1			
55-70	1.67	0.97	Nd	Nd	Nd			

Nd= not determined

Table 4. Mechanical composition and FrsRLer soil texture

Horizon	Depth (cm)	Ag (2.0-0.2)	Af (0.2-0.02)	Lg (0.02-0.01)	Lf (0.01-0.002)	Clay < 0.002	Texture
Profile 2 (little eroded)							
Aer	0-13	34.53	8.00	4.00	6.00	47.47	Clayey
B_1	13-24	30.53	6.00	3.28	6.00	54.19	Clayey
B_{21}	24-43	31.81	6.00	4.00	6.00	52.19	Clayey
$B_{22}t$	43-71	29.25	6.00	4.00	4.00	56.75	Clayey
Profile 5 (little eroded)							
Aerp	0-18	40.53	6.00	6.00	4.00	43.47	Sandy clay
B_1t	18-41	32.37	8.00	4.00	6.00	51.63	Clayey
B_2t	41-66	34.53	6.00	3.28	6.00	50.19	Clayey
Profile 6 (strongly eroded)							
BAer	0-14	39.25	8.00	4.00	4.00	44.75	Sandy clay
Bt	14-40	38.37	4.00	3.00	1.28	53.35	Clayey
BCgr	40-60	39.25	6.00	2.00	4.00	48.75	Clayey

Ag: coarse sand, Af: fine sand, Lg: coarse silt, Lf: fine silt

Table 5. Physical-chemical characteristics of the FrsRLer soil

Depth	pH		OM	P_2O_5	K_2O	Exchangeables cations(cmol kg^{-1})				
(cm)	H_2O	KCl	(%)	mg $100g^{-1}$	mg $100g^{-1}$	Ca^{++}	Mg^{++}	Na^+	K^+	Sum
Profile 2 (little eroded)										
0-13	6.0	5.9	3.97	3.2	9.0	29.5	4.5	0.07	0.19	34.3
13-24	5.0	4.6	2.34	3.2	7.5	26.5	8.0	0.12	0.16	34.8
24-43	5.1	4.9	2.94	4.4	8.4	23.5	9.0	0.09	0.18	32.8
43-71	5.2	4.9	1.88	3.9	3.9	29.0	4.0	0.16	0.14	33.3
Profile 5 (little eroded)										
0-18	6.5	6.2	3.37	3.4	9.8	18.5	4.5	0.13	0.21	23.3
18-41	5.7	4.8	2.20	3.0	5.6	20.0	2.5	0.14	0.12	22.8
41-66	5.9	5.2	1.88	7.1	7.1	16.0	4.5	0.15	0.13	20.8
Profile 6 (strongly eroded)										
0-14	6.1	5.9	2.55	3.0	3.3	15.0	3.0	0.10	0.07	18.2
14-40	5.7	5.8	2.34	3.2	3.7	18.5	4.0	0.10	0.08	22.7
40-60	5.4	5.4	2.22	4.6	6.6	19.0	2.0	0.23	0.14	21.4

With respect to the OM content in the slightly eroded soils, it is not low, but between 3 and 4, which is classified as medium; but in the strongly eroded soils it is less than 3.0 %, so they are considered as low (26). These differences are also manifested in the COR, being the strongly eroded profile with a lower amount of CO than all the previous soils. When compared with the humic subtype, it can be seen that the latter have a higher content in OM and, therefore, in COR (Table 6).

It is noteworthy that these soils, despite being erogenous, are not so low in OM or COR, which may be related to the action of the vegetation that previously existed on that surface, which was marabú. This type of vegetation over many years leads to the enrichment of OM and nitrogen to the soil. It is possible that in time with the pasture that is implanted between the trees either with moringa or acerola, these soils reach the humic category. In addition, the Red Red Leached Phersialytic soils have a certain evolution, with a relatively high content of free iron, estimated at 6-7 %. It should be noted that recent studies show that tillage activates iron to prevent soil organic carbon loss after conversion from forest to cornfields in tropical acid red soils (27).

Losses in COR in FrsRL soils due to erosion

As can be seen from the results of these investigations (Table 7), the profiles taken under marabú have a higher COR content than the erogenous soils, both for the 0-20 cm layer and the 0-50 and 0-100 cm layers. If a generalization is made by averaging the COR in these profiles, it is obtained that for the 0-20 cm layer, the soils with marabú cover have 74 ton ha^{-1} of COR; while those that are slightly eroded have 55 and those that are moderately eroded have 40 t ha^{-1} of COR. Therefore, the slightly eroded soils have lost 19-ton ha^{-1} of COR and the moderately eroded soils 34 t ha^{-1} of COR.

The elimination of the marabú as secondary vegetation that was established in these soils, in undulating hilly relief, resulted in the manifestation of the erosion process, with losses of the A horizon, which at the same time leads to losses of COR. This problem has been studied in other regions, where it is evident that soil erosion leads to the loss of OM and therefore COR (28-32).

The problem of carbon losses in soils is a current research topic, since carbon capture and sequestration by

Table 6. FrsRLer soil carbon content and reserves

Depth	OM	C	Dv	W	Reserves of C	Reserves of C ($Mg\ ha^{-1}$)		
(cm)	(%)	(%)	($kg\ dm^{-3}$)	(%)	($Mg\ ha^{-1}$)	0-20	0-30	0-50
Profile 2 (little eroded)								
0-13	3.97	2.30	1.21	17	36.1	49	71	114
13-24	2.34	1.36	1.33	24	19.9			
24-43	2.94	1.71	1.45	28	47.1			
43-71	1.88	1.09	1.49	22	45.5			
Profile 5 (little eroded)								
0-18	3.37	1.95	1.49	21	52.30	60	75	112
18-41	2.20	1.28	1.50	19	44.16			
41-66	1.88	2.09	1.62	18	43.87			
Profile 6 (strongly eroded)								
0-14	2.55	1.48	1.36	18	28.18	40	59	99
14-40	2.34	1.36	1.41	12	49.86			
40-60	2.22	1.29	1.60	13	41.28			

Table 7. Comparative table by COR content ($t\ ha^{-1}$) in FrsRL soils

Soils	FrsRLmh (Profiles 1 and 4)	Diagnostic profile: $A_{11}h$-$A_{12}h$-B-BCgr-CRca-Rca and $A_{11}m$-$A_{12}m$-Bt-CRca-R			
		COR	0-20	0-30	0-50
			64	83	Nd
			84	111	148
	FrsRLer lightly eroded (Profiles 2 y 5)	Diagnostic profile: Aer-B_1-B_{21}-B_{22}t and Aerp-B_1-B_2t-B_3gr-CRca			
		COR	0-20	0-30	0-50
			51	73	115
			60	75	112
	FrsRLer strongly eroded (Profiles 6)	Diagnostic profile: BAer-Bt-BCgr			
		COR	0-20	0-30	0-50
			40	59	99

soils is one of the most important measures to avoid CO^2 emissions to the atmosphere and therefore to combat climate change (CC) (33-38). These losses largely enrich the so-called Greenhouse Gases (GHG), which in turn is leading to the warming of the atmosphere that causes the so-called CC, mainly due to land use change and inadequate land management practices (39-43).

On the other hand, losses in COR lead to the deterioration of different soil properties (44). Considering the importance of this problem, some research has been carried out in Cuba that shows how COR losses in Ferrallitic Red Leached soils of the karst plains negatively influence other soil properties (45). The results obtained serve as indicators to establish the subtype of agrogenic soils in this type of soil, according to the Cuban soil classification (9). In the same way, results have been obtained recently on the quantification of these losses in $t\ ha^{-1}\ year^{-1}$ for these soils, according to their use (46).

Fersialitic Red Gleyic Leached Soil

They are mainly located in landscape II, on the fluvial terraces towards the dam. For their agricultural use, it is important to take into account the slope, since some of them are located in the intermediate part between the slope and the lower part near the streams. Despite the fact that this soil is located in a relatively high part of the relief, there are symptoms of gleyzation in it, as a result of a formation with more influence of excess moisture than at present. This situation is changing as the relief was ascending by the neotectonic movements in the Quaternary period (5), and does not have that influence as marked as it occurs in the lower parts of the relief, where the gleyzation is current by the stains that the soil presents, due to the oxidation process reduction by the temporary stagnation that occurs in times of rain. In other words, in this part of the relief, gleyic subtypes can be formed, while in the lower terraces the soils are Gleysols (1,10).

CONCLUSIONS

- The study of the detailed characterization of Fersialitic grouping soils made it possible to clarify their classification, as well as to demonstrate that the fertility levels of essential elements, assimilable phosphorus and potassium, are very low.
- The FrsRL soil has several subtypes; in conserved areas the FrsRL soil is humic, and fluffy in the higher parts of the relief. In lower regions, gleyic FrsRL soil is formed. In addition, due to soil loss due to anthropogenic causes, the subtypes FrsRL erogenic and FrsRL erogenic and gleyic are classified.

RECOMMENDATIONS

- To take into consideration this work results for the possibility of opening a new genetic type of Leached Red

Fersialitic in the next version of the Cuban Soil Classification.

- To develop actions to increase the phosphorus and potassium content of the soil, and, at the same time, to achieve an adequate nutrition of protein plants (moringa, mulberry, tithonia and cratylia) in the productive unit.
- Update soil fertility through agrochemical sampling every four years. In addition, monitor the carbon status since it would be very important for the capture and sequestration of carbon by the protein plants present on the farm.

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